P
Agric
Entomological
& Medical

August 1919. Chemical Series. Vol. V, No. 5.

Memoirs of the Department of Agriculture in India

STORAGE

THE PHOSPHATE REQUIREMENTS OF SOME LOWER BURMA PADDY SOILS

BY

F. J. WARTH, M.Sc., B.Sc

Agricultural Chemist to the Government of Burma

AND

MAUNG PO SHIN

Assistant to the Agricultural Chemist to the Government of Burma

MAR 4 1958

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Price, Re. 1-12 or 3s. 3d.

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

The Council of the Pusa Agricultural Research Institute.

http://www.archive.org/details/n5memoirschemica05impeuoft

August, 1919. CHEMICAL SERIES. VOL. V, NO. 5.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

THE PHOSPHATE REQUIREMENTS OF SOME LOWER BURMA PADDY SOILS

BY

F. J. WARTH, M.Sc., B.Sc

Agricultural Chemist to the Government of Burma

AND

MAUNG PO SHIN

Assistant to the Agricultural Chemist to the Government of Burma

THE ROYAL CANADIAN INSTITUTE

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Agents for the Sale of Government Publications.

IN THE UNITED KINGDOM.

Constable & Co., 10, Orange Street, Leicester Square, London, W.C.
Kegan Paul, Trench Trübner & Co., 68-74, Carter Lane, E.C., and 25, Museum Street, London, W.C.
Bernard Quaritch, 11, Grafton Street, New Bond Street, London, W.
P. S. King & Sons, 2 and 4, Great Smith Street, Westminster, London, S.W.
H. S. King & Co., 65, Cornhill, E.C., and 9, Pall Mall, London, W.
Grindlay & Co., 54, Parliament Street, London, S.W.
T. Fisher Unwin, Ld., 1, Adelphi Terrace, London, W.C.
W. Thacker & Co., 2, Creed Lane, London, E.C.
Luzac & Co., 46, Great Russell Street, London, W.C.
B. H. Blackwell, 50 and 51, Broad Street, Oxford.
Deighton, Bell & Co., Ld., Cambridge.
Oliver & Boyd, Tweeddale Court, Edinburgh.
E. Ponsonby, Ld., 116, Grafton Street, Dublin.

ON THE CONTINENT.

Ernest Leroux, 28, Rue Bonaparte, Paris.
Martinus Nijhoff, The Hague, Holland.

IN INDIA AND CEYLON.

Thacker, Spink & Co., Calcutta and Simla.
W. Newman & Co., Calcutta.
R. Cambray & Co., Calcutta.
S. K. Lahiri & Co., Calcutta.
B. Banerjee & Co., Calcutta.
The Indian School Supply Depôt, 309, Bow Bazar Street, Calcutta, and 226, Nawabpur, Dacca.
Butterworth & Co. (India), Limited, Calcutta.
The Weldon Library, 18-5, Chowringhee Road, Calcutta.
Rai M. C. Sircar Bahadur and Sons, 75-1-1, Harrison Road, Calcutta.
Higginbothams, Ld., Madras.
V. Kalyanarama Iyer & Co., Madras.
G. A. Natesan & Co., Madras.
S. Murthy & Co., Madras.
Thompson & Co., Madras.
Temple & Co., Madras.
P. R. Rama Iyer & Co., Madras.
Thacker & Co., Ld., Bombay.
A. J. Combridge & Co., Bombay.
D. B. Taraporevala, Sons & Co., Bombay.
Radhabai Atmaram Sagoon, Bombay.
Sunder Pandurang, Bombay.
Gopal Narayan & Co., Bombay.
Ramchandra Govind & Son, Kalbadevi, Bombay.
N. B. Mathur, Superintendent, Nazir Kanun-i-Hind Press, Allahabad.
A. Chand & Co., Lahore, Punjab.
Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore.
Superintendent, American Baptist Mission Press, Rangoon.
S. C. Talukdar, Proprietor, Students and Company, Cooch Behar.
A. M. & J. Ferguson, Colombo, Ceylon.

THE PHOSPHATE REQUIREMENTS OF SOME LOWER BURMA PADDY SOILS.

BY

F. J. WARTH, M.Sc., B.Sc.,

Agricultural Chemist to the Government of Burma,

AND

MAUNG PO SHIN,

Assistant to the Agricultural Chemist to the Government of Burma.

[Received for publication on 10th September, 1918.]

THE work consisted of soil analyses combined with suitable pot culture tests to show up deficiencies in phosphoric acid.

I. SOIL ANALYSES.

Regarding the method of soil analysis employed it should be stated that extraction was effected by continuous boiling of the ignited soil with concentrated HCl for 8 hours. The soluble silica was determined in the residue by boiling with Na_2CO_3 solution. Total phosphoric acid was determined by extraction of the unheated soil with nitric-hydrochloric acid. Complete results are given in the appendix (Table A).

Allowing for differences due to texture the soils fall according to chemical composition into a few distinct groups. The soils around Nyaunglebin and Daiku are evidently fairly new compared with most of the others. These soils, though low in lime, are high in potash and phosphoric acid. The soils of the Hlaing valley along the Prome line are quite as new as the above. They are high in magnesia, potash, and phosphoric acid, but low in lime.

From the neighbourhood of Toungoo we get samples of soils which are probably much older. They have certainly suffered extensive leaching out and are distinctly poor in lime, potash, magnesia, and phosphoric acid.

Finally, the soil samples of Pegu, Insein and Hanthawaddy districts have given almost invariably very low lime, potash, magnesia, and phosphoric acid figures. Most of these soils are undoubtedly old and have suffered severe leaching out. The newer soils are neutral or acid. The remainder are all acid, the acidity varying to a degree which is at present inexplicable. It has not been found to conform with any agricultural characters so far studied.

In addition to the marked variation in phosphoric acid content as we pass from one soil area to another, there is also a definite relationship between phosphoric acid content and soil texture irrespective of the source of the soil. This is by no means surprising but the extent of this correlation in the case of the Lower Burma soils is worth noting. It is clearly shown in a table given later (Table V) in which the soils have been divided into groups according to texture. (For this purpose it is assumed that the texture of a soil is roughly indicated by the soluble silica figures.) This table shows that the available phosphoric acid as determined by citric acid extraction increases generally with the total phosphoric acid content, the availability increasing on the whole more rapidly than the total phosphoric acid.

Some figures for available phosphoric acid are noticeably peculiar, *e.g.*, Daiku and Prome ; Pyinbongyi A and Thilawa. If the availability data are significant, growth of plants on these soils should bring out noticeable differences.

The phosphoric acid content of Hmawza soil is quite unique.

II. POT CULTURE TESTS.

These were manurial trials to determine the effect of phosphoric acid and nitrogen, separately and combined. Potash was also tested but gave in no case conclusive figures.

Each manurial test was made in four pots, and, as a check, four unmanured pots were also tested with each soil. Some typical photographs of pots are shown in Plates I—IV. These illustrate the regularity of growth and the satisfactory maturing of the crop.

Culture tests with all the soils could not be carried out in one year. The work was distributed over three seasons, and therefore both the rate of development and the final crop yields are considerably affected by climate.

In one sense this is undoubtedly a disadvantage as it prevents a close comparison of all data. On the other hand, as will be seen later, the indications of shortage in phosphoric acid were very similar each year in spite of climatic differences. The work has therefore gained considerably in value from the assurance that the effects are similar under varying climatic conditions.

The pot cultures yielded data under the following heads :—

(1) Crop yields of seed and straw at harvest.
(2) Rate of development of crop.
(3) Composition of crop at harvest.

Full results obtained are shown in the appendix (Tables B, C, and D).

Before we can utilize these figures it is necessary to discuss the accuracy of the results and the accuracy required to make the conclusions certain.

TABLE I.

Showing variations in pot culture crop yields.

	Soil		Unmanured pots					Nitrogen pots					Nitrogen + P_2O_5 pots				
			1	2	3	4	Average	1	2	3	4	Average	1	2	3	4	Average
1915	Nyaunglebin B	Seed	9	8·5	10·5	8	9·0 (0·8)	31	38	36	33	34·5(2·5)	32	36	37	34	35·0 (1·8)
		Straw	13·5	13	12	12	12·6 (0·6)	94	91	81	79	86·0 (6·2)	84	88	90	92	88·5 (2·5)
	Dabein B	Seed	11	11	17	18	14·0 (3·2)	30	31	27	30	29·5 (1·2)	38	42	34	40	38·5 (2·5)
		Straw	12	20	21	25	19·5 (3·8)	49	38	33	38	39·5 (4·8)	85	94	84	88	88·0 (3·2)
1916	Tantabin	Seed	35	31	25	28	30·0 (3·2)	51	59	44	54	52·0 (4·5)	45	50	57	53	51·0 (3·8)
		Straw	42	35	30	33	35·0 (3·5)	101	109	76	104	97·5 (10·8)	94	96	111	106	102·0 (6·5)
	Insein A	Seed	20	20	20	20	20·0 (0·0)	30	28	30	29	29·0 (0·8)	40	38	39	43	40·0 (1·5)
		Straw	27	26	26	30	27·0 (1·2)	46	44	45	50	46·0 (1·8)	100	104	100	100	101·0 (1·5)
1917	Thonze	Seed	42	37	36	39	38·5 (2·0)	60	64	60	64	62·0 (2·0)	69	61	60	65	64·0 (3·2)
		Straw	50	52	47	51	50·0 (1·5)	104	113	105	104	106·5 (3·2)	101	101	107	110	105·0 (3·8)
	Thilawa	Seed	21	26	26	29	25·5 (2·2)	35	27	34	40	34·0 (3·5)	48	50	56	58	53·0 (4·0)
		Straw	37	38	38	37	37·5 (0·5)	38	40	45	46	42·0 (3·2)	102	100	105	100	102·0 (1·8)

1. Variations in pot culture crop yields.

Table I gives the actual weighments of the crops of two typical soils for each of the years during which the tests were in progress. Even these figures suffice to show that the year 1915 was decidedly the least favourable for growth. The full Table B brings out this point more conclusively, and indicates that 1917 was somewhat more favourable than 1916.

No attempt has been made to work out in these tables the probable error either of the mean or of the individual pots. It is not feasible when only four pots are available for comparison.

The mean deviation of individual results from the average is however entered in brackets in each case, and, as will be seen, this is quite sufficient to give us confidence in the data.

Amongst all the results obtained there is none so doubtful as the average yield for Dabein B soil unmanured.

Here we have (Table I) from two identically treated pots a yield in one case practically double that of the other. The mean deviation from the average is in this case $\pm$ 3·8 or 20 per cent. of the total. This is however quite an exceptional extent of variation. It is worth noticing that even this very serious variation does not approach the differences produced by manuring.

A much more usual case is that illustrated by Tantabin where with nitrogen manure one decidedly low figure and with nitrogen plus phosphoric acid one decidedly high figure are obtained.

The mean deviations in this series are small and obviously quite negligible compared with differences produced by manuring.

The significance of the variations will, however, depend entirely upon the use to which the figures are to be put. It is to show this use that the soils in Table I have been selected.

Neglecting for the present the low yields of 1915 and comparing only the soils of that year, we see that in both cases nitrogen has produced an increase in crop which is far in excess of the mean deviation. The increase with Nyaunglebin is, however, much greater than with Dabein. The effect of nitrogen plus phosphoric acid on Nyaunglebin is scarcely greater than that of nitrogen alone—the difference being of the same order of magnitude as the deviation and therefore not significant.

With Dabein, on the other hand, addition of phosphoric acid leads to a further very marked increase, and this increase being of quite a different order to the mean deviations is undoubtedly significant.

The full data are given in these cases to show that the reliability of the conclusions arrived at cannot be questioned.

Exactly the same point is brought out by the two 1916 and the two 1917 soils.

In all these cases the differences for which we are looking are far greater than the mean experimental error.

A reference to the full Table B shows that practically all the soils examined behave either as one or other of the typical soils just discussed in detail, and that all mean deviations are much less than differences due to manuring.

So long therefore as the crop weighings are utilized solely to differentiate between soils which do and soils which do not give decided increase when phosphoric acid is added to nitrogen manure, we know that the conclusions cannot be vitiated by experimental errors.

It is important to note that similar differences of crop yield are obtained both in favourable and in unfavourable seasons. There is no doubt therefore that seasonal variations do not affect our conclusions regarding soils distinctly rich and distinctly poor in phosphoric acid. The few intermediate samples might be expected to give somewhat divergent results according to the nature of the season, but on the whole there is little evidence in favour of this view.

2. Variations in rate of development.

The rate of development was determined by periodical measurement of the pot plants. The numbers given in Table C are the product of average height of plant multiplied by number of tillers. Each figure given is the average development found in four identically treated pots. The figures are not exact because they do not take into account the thickness of the stems or the amount of foliage. These are, however, generally proportional to the stem development at any given stage of growth, and may therefore without serious error be neglected.

The rate of growth is modified so very greatly by manuring that much cruder figures and even eye estimation alone would serve to bring out the essential points. That this is the case will be seen by referring to the plates showing photographs of typical pots.

Development figures corresponding to the photographs are given below.

TABLE II.

Showing initial development figures corresponding to pot culture photographs.

	Daiku	Tantabin A	Insein A	Pyinbongyi B
Unmanured	575	200	200	400
N alone	1,100	900	300	375
$N + P_2O_5$	1,248	900	900	1,054

These figures, looked at in conjunction with the photographs, will show that the development data are intended to express in a concrete form such great differences as are evident from eye inspection. Indeed the evidence from the rate of development of the plants is so clear that all the necessary proof could have been given by photographs alone. The full development data given in Table C prove that the photographs are not a collection of exceptionally striking differences.

They are quite typical of the results obtained throughout. We have a number of ether photographs of identical effects with other soils, and there is no question from their evidence also that the development figures are a very fair numerical representation of differences which are striking to the eye.

In this case also climate plays an important part in the rate of development, and as with total crop yields already discussed so here it is impossible to come to any conclusions by comparing rates of development in different seasons.

However if we compare the effect of nitrogen alone and nitrogen plus phosphoric acid, we obtain typical differences between (*a*) soils which show no acceleration with nitrogen alone and great acceleration with nitrogen plus phosphoric acid, and (*b*) soils which show very marked acceleration with nitrogen alone and little or no further acceleration with nitrogen plus phosphoric acid. This phenomenon is observed equally clearly in favourable and unfavourable seasons, and may therefore also be used with confidence to differentiate soils.

3. CROP ANALYSIS.

Each figure in Table D gives the phosphoric acid content of the mixed and finely divided straw harvest from four identically treated pots. This precludes the inclusion of any unrepresentative result due to peculiar growth in a single pot. Table D shows that very striking differences exist in phosphoric acid content of straw from different soils. In this case we have not got analyses of individual pots by which the mean deviation and thence the reliability of the figures can be estimated.

We have evidence of another kind however which is quite as convincing and this should be considered here.

When an unmanured soil gives a crop poor in phosphoric acid, it is to be expected that by increasing the crop with nitrogen manuring the crop will become still poorer in phosphoric acid content. This is found to be invariably the case.

Further, if phosphoric acid be added to the nitrogen and the crop thereby be still further increased, it may be expected still to remain somewhat poorer than the average. This is also found to be the case where the soil seriously lacks phosphoric acid.

In no case therefore is the evidence based on less than three analyses each of which represents the mean crop composition of four pots. The same remarks apply to soils which produce straw rich in phosphoric acid.

Straw analyses for a few soils are wanting. This was due to the fact that some plants were attacked by disease and had to be cut out before maturity. The evidence regarding these soils is therefore unavoidably incomplete.

4. Tests used in establishing the phosphoric requirements of soils.

Soils poor in phosphoric acid may be expected to give increased yields when phosphoric acid is supplied. Very few indeed of the soils tested show this effect. Hmawbi, Hlegu D, Kyauktan, and Thilawa gave slightly increased crops with phosphoric acid. The effect was also just noticeable with Thongwa, Dabein A, and Hlegu C.

It is fairly evident, however, that this is not a complete list of the soils which are poor in phosphoric acid. It does not include some of the very poorest.

There exists therefore a very serious difficulty. This must be considered, but it would be better dealt with when the other evidence has been summarized. This is as follows :—

(a) *Lack of soil phosphoric acid indicated by initial development.*

In Table III some soils which show most characteristic differences in rate of initial development are collected together. (Figures from Table C.) We are not concerned here with the actual rate of growth which must vary with soil and climate, but with the differences produced by nitrogen alone and nitrogen and phosphoric acid on the initial growth.

TABLE III.

Showing rate of initial growth in soils poor and rich in phosphoric acid.

(a) *Soils poor in phosphoric acid.*

	Dabein A	Dabein B	Ledaung-gan A	Ledaung-gan B	Hlegu C	Kyauktan	Thilawa
Unmanured ...	76	72	60	85	120	240	290
N alone ...	80	80	60	85	120	240	480
N + P_2O_5 ..	480	440	240	240	240	1,050	910

(b) *Soils rich in phosphoric acid.*

	Nyaungle-bin B	Hmawza	Paungde	Sitkwin	Thonze	Daiku	Tantabin
Unmanured ...	114	500	270	500	530	575	200
N alone ...	550	1,300	880	810	1,090	1,240	900
N + P_2O_5 ...	550	1,300	880	810	1,090	1,180	900

This is undoubtedly the most striking point brought out by the pot cultures. With this criterion the soils can be divided very sharply into two groups, namely, (*a*) those which give little or no initial increase with nitrogen alone and give an increase when phosphoric acid is supplied in addition, and (*b*) those which show very marked acceleration with nitrogen alone and practically no further increase when phosphoric acid is added.

There can be no question that according to this test a number of soils are proved to be poor in phosphoric acid and a number well supplied with this ingredient.

The full development Table C shows that all the soils tested can be classified in this way. The figures available for most of the other soils are quite as convincing as those shown above. A few soils give intermediate results. The extent of Table C, however, makes it difficult for the eye to note the striking character of the evidence available.

To show this adequately it was necessary to give a few figures in a smaller table.

(b) *Lack of soil phosphoric acid indicated by final straw yields.*

Table IV gives the increase in the final straw harvest produced by nitrogen alone and by nitrogen plus phosphoric acid on same typical soils.

In this case nitrogen alone invariably produces a marked increase. In certain soils, however, the addition of phosphoric acid produces a further very pronounced increase, whilst in others nitrogen alone produces practically a maximum crop which is scarcely affected by addition of phosphoric acid.

TABLE IV.

Straw harvest from soils which are respectively poor and rich in P_2O_5.

(a) *Soils poor in P_2O_5.*

	DABEIN A		DABEIN B		LEDAUNGGAN A		LEDAUNGGAN B		HLEGU C		KYAUKTAN		THILAWA	
	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5
Unmanured ..	17·4	0·085	19·5	0·120	11·2	0·110	20·6	0·081	35·5	0·099	42·5	0·089	37·0	0·049
N alone ...	35·5	0·033	39·5	0·049	35·0	0·039	35·0	0·029	39·0	0·034	80·5	0·066	42·0	0·027
N + P_2O_5 ...	81·5	0·261	88·0	0·201	68·0	0·210	75·0	0·235	69·0	0·212	112·5	0·260	102·0	0·164

(b) *Soils rich in P_2O_5.*

	NYAUNGLEBIN B		HMAWZA		PAUNGDE		SITKWIN		THONZE		DAIKU		TANTABIN	
	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5	Straw	% P_2O_5
Unmanured ...	12·6	0·307	54·0	0·452	33·5	0·357	42·0	0·572	50·0	0·420	61·2	0·277	33·0	0·352
N alone ...	86·2	0·343	123·0	0·407	95·0	0·435	101·0	0·415	106·5	0·385	125·0	0·335	97·5	0·356
N + P_2O_5 ...	88·5	0·377	126·5	0·473	92·0	0·413	99·0	0·505	105·0	0·439	135·0	0·325	102·0	0·351

Here again there is a very sharp distinction between the soils, and we are able to specify some as decidedly poor in and others definitely well supplied with phosphoric acid.

The full table of crop yields (B) shows that most of the soils tested can be classified in this way.

(c) *Lack of soil phosphoric acid indicated by phosphoric acid in straw harvest.*

These figures are particularly instructive if considered in connection with straw yield. Hence both sets of figures are included in Table IV.

There are two points worth noting in these results :—

(1) When phosphoric acid is low in a crop of unmanured soil it is usually still lower in the nitrogen manured crop. It looks as if the plant had extracted practically all the phosphoric acid it could, and making the crop larger results simply in the formation of more organic matter containing still the same amount of phosphoric acid.

(2) The straw analyses corroborate in a really very convincing manner the conclusions derived from a study of the straw yields.

The full Table D of straw analyses gives similar data for the other soils.

This table should be compared with development Table C. It will be seen that in soils poor in phosphoric acid nitrogen causes no initial increase whatever in growth. The plant at this stage is evidently searching for phosphoric acid. Later it grows at a maximum rate compatible with the phosphoric acid it has obtained, the final crop being much greater than the unmanured plants. The nitrogen manured plants which may be aptly called forced are decidedly abnormal in composition. But Table D shows that even without nitrogen manuring some of the poorest soils produced abnormal plants.

Such plants are very likely to have weaknesses which will manifest themselves in times of drought and during insect attacks. Mr. McKerral, Deputy Director of Agriculture, Southern Circle, Insein, made an observation which bears on this point.

He found that during a favourable season phosphatic manure gave no appreciable increase on Hmawbi farm soil. During an unfavourable season the unmanured plot gave a poor yield owing to insect attack. The adjacent plot manured with phosphoric acid was not appreciably affected and gave a good yield. This result is strikingly corroborated by our pot culture crop analyses.

In the small Tables III and IV (which are amply supported by the full figures of Tables B, C, and D) the evidence regarding lack of phosphoric acid is shown in as obvious and concise a manner as possible. It was necessary to go over this evidence in detail because many of the soils found to be poor in phosphoric acid by these tests gave no appreciable effect with phosphoric acid alone.

The evidence from phosphoric acid manuring alone is therefore quite contradictory. It will be ignored for the present, and we will proceed to classify our soils according to the tests given above.

5. Classification of soils according to phosphoric acid requirements.

In Table V all the soils examined have been classified according to each of the three methods described.

Table V.

Test	Soils poor in P_2O_5	Intermediate	Soils rich in P_2O_5
1. Effect of Am_2SO_4 with and without P_2O_5 on final yield.	Hmawbi, Kyungon B, Pyinbongyi B, Insein A, Dabein A & B, Pegu B, Ledaunggan A & B, Hlegu C & D, Kyauktan, Thilawa, Thongwa.	Pyinbongyi A	Daiku, Insein B, Tantabin, Nyaunglebin A & B, Pegu A, Hlegu A & B, Kayan, Prome, Thegon, Hmawza, Zigon, Nattalin, Sitkwin, Thonze.
2. Effect of Am_2SO_4 with and without P_2O_5 on initial development.	Hmawbi, Yedashe B, Kyungon A & B, Pyinbongyi A & B, Insein A, Dabein A & B, Pegu B, Ledaunggan A & B, Hlegu C & D, Kyauktan, Thilawa, Thongwa.	Yedashe A, Nyaunglebin A.	Daiku, Insein B, Tantabin, Nyaunglebin B, Pegu A, Hlegu A & B, Kayan, Prome, Thegon, Hmawza, Zigon, Nattalin, Sitkwin, Thonze.
3. Chemical analysis of crop.	Kyungon B, Pyinbongyi B, Insein A & B, Dabein A & B, Ledaunggan A & B, Hlegu C & D, Kyauktan, Thilawa.	Pyinbongyi A, Pegu B, Thongwa.	Daiku, Tantabin, Nyaunglebin A & B, Pegu A, Hlegu A & B, Kayan, Prome, Thegon, Hmawza, Zigon, Nattalin, Sitkwin, Thonze.

With very few exceptions all three tests lead to identical conclusions. This in itself is a proof that the tests are satisfactory. Insein B is a striking exception. This soil produces large crops with nitrogen alone, shows little or no further increase with phosphoric acid, and would naturally be classed as a soil rich in phosphoric acid. The straw analysis, however, indicates serious poverty. A similar result has been obtained before with another sandy soil. In consequence of the very poor straw the soil must be classed as poor. Pyinbongyi A gives intermediate results in two cases although its content of

phosphoric acid is low. At all events it does not approach the reactions of a rich soil. Nyaunglebin A shows slight weakness but on the whole it is associated closely with the rich soils.

6. Relation between cultural tests and the phosphoric acid content of soils.

To bring out this relationship, the summary of information derived from pot cultures (Table V) must be considered in conjunction with soil analysis results. For this purpose Table VI has been prepared.

Table VI.

Serial No.	Name of soil	Soluble silica	Nitrogen	Total P_2O_5	Available P_2O_5	Pot cultures
1	Hlegu A	20·96	0·128	0·07	0·0044	Rich
2	Nyaunglebin A	18·97	0·116	0·08	0·0070	,,
3	Yedashe A	17·91	0·099	0·04	0·0048	Poor
4	Ledaunggan A	17·05	0·128	0·03	0·0017	,,
5	Paungde	16·79	0·131	0·10	0·0150	Rich
6	Zigon	16·39	0·139	0·08	0·0080	,,
7	Daiku	16·41	0·113	0·07	0·0187	,,
8	Ledaunggan B	16·15	0·133	0·04	0·0019	Poor
9	Nyaunglebin B	15·97	0·079	0·11	0·0213	Rich
10	Thegon	15·32	0·142	0·11	0·0279	,,
11	Prome	15·40	0·078	0·07	0·0036	,,
12	Hmawbi	15·26	0·072	0·03	0·0029	Poor
13	Nattalin	15·10	0·168	0·13	0·0373	Rich
14	Dabein A	12·99	0·107	0·03	0·0011	Poor
15	Insein A	12·45	0·105	0·02	0·0009	,,
16	Hlegu D	12·47	0·116	0·02	0·0007	,,
17	Pyinbongyi A	11·94	0·089	0·03	0·0057	,,
18	Thilawa	11·62	0·116	0·03	0·0023	,,
19	Dabein B	10·63	0·084	0·02	0·0010	,,
20	Hlegu B	10·33	0·076	0·05	0·0045	Rich
21	Thongwa	10·24	0·119	0·04	0·0057	Poor
22	Sitkwin	10·03	0·076	0·08	0·0304	Rich
23	Kyauktan	9·95	0·105	0·03	0·0012	Poor
24	Thonze	9·38	0·081	0·06	0·0134	Rich
25	Hmawza	8·94	0·076	0·39	0·2360	,,
26	Kayan	8·76	0·081	0·05	0·0189	,,
27	Tantabin B	8·51	0·057	0·09	0·0468	,,
28	Tantabin A	8·38	0·051	0·09	0·0449	,,
29	Yedashe B	8·32	0·053	0·01	0·0012	Poor
30	Pegu B	7·99	0·061	0·02	0·0030	,,
31	Pegu A	7·07	0·072	0·03	0·0039	Rich
32	Kyungon B	6·56	0·065	0·01	0·0009	Poor
33	Hlegu C	6·25	0·087	0·02	0·0013	,,
34	Kyungon A	6·08	0·051	0·01	0·0009	,,
35	Pyinbongyi B	5·51	0·068	0·02	0·0020	,,
36	Insein B	3·91	0·104	0·02	0·0016	,,

This table shows in the first place that with Lower Burma soils the figures for total phosphoric acid are on the whole better than the availability figures as an index of lack of phosphoric acid. For example, amongst the first three soils on the list the availability figures for Yedashe and Hlegu A are the same,

The figures for total phosphoric acid of these two soils are very different and lead one to expect Yedashe to be the poorer. This conclusion is corroborated by the culture test.

Again No. 11 Prome compared with No. 17 by available figure should be poor. Pot tests show that it is not poor, and here again the figure for total phosphoric acid is the better index.

Hlegu B (No. 20) and Thongwa (No. 21) should according to availability figure be about the same with perhaps a slight advantage in favour of Thongwa. Pot cultures showed that Hlegu B was richer than Thongwa, and this agrees with the figures for total phosphoric acid.

It should be noted that in each of these cases we are comparing soils of similar texture, and that therefore the conclusions are better justified than they otherwise would be.

The data can be used further to estimate the amount of soil phosphoric acid which may be considered sufficient.

Amongst the denser soils, Nos. 3 and 8, containing 0·04 per cent. phosphoric acid, show lack of phosphoric acid. The next higher figures are Nos. 1 and 7 with 0·07 per cent. These show no lack of phosphoric acid ; No. 2 containing 0·08 per cent., however, showed some signs of weakness. Soils of this kind must therefore contain 0·07 or 0·08 per cent. phosphoric acid to be satisfactory.

In the second group there are no soils near the limit and an estimate cannot be made.

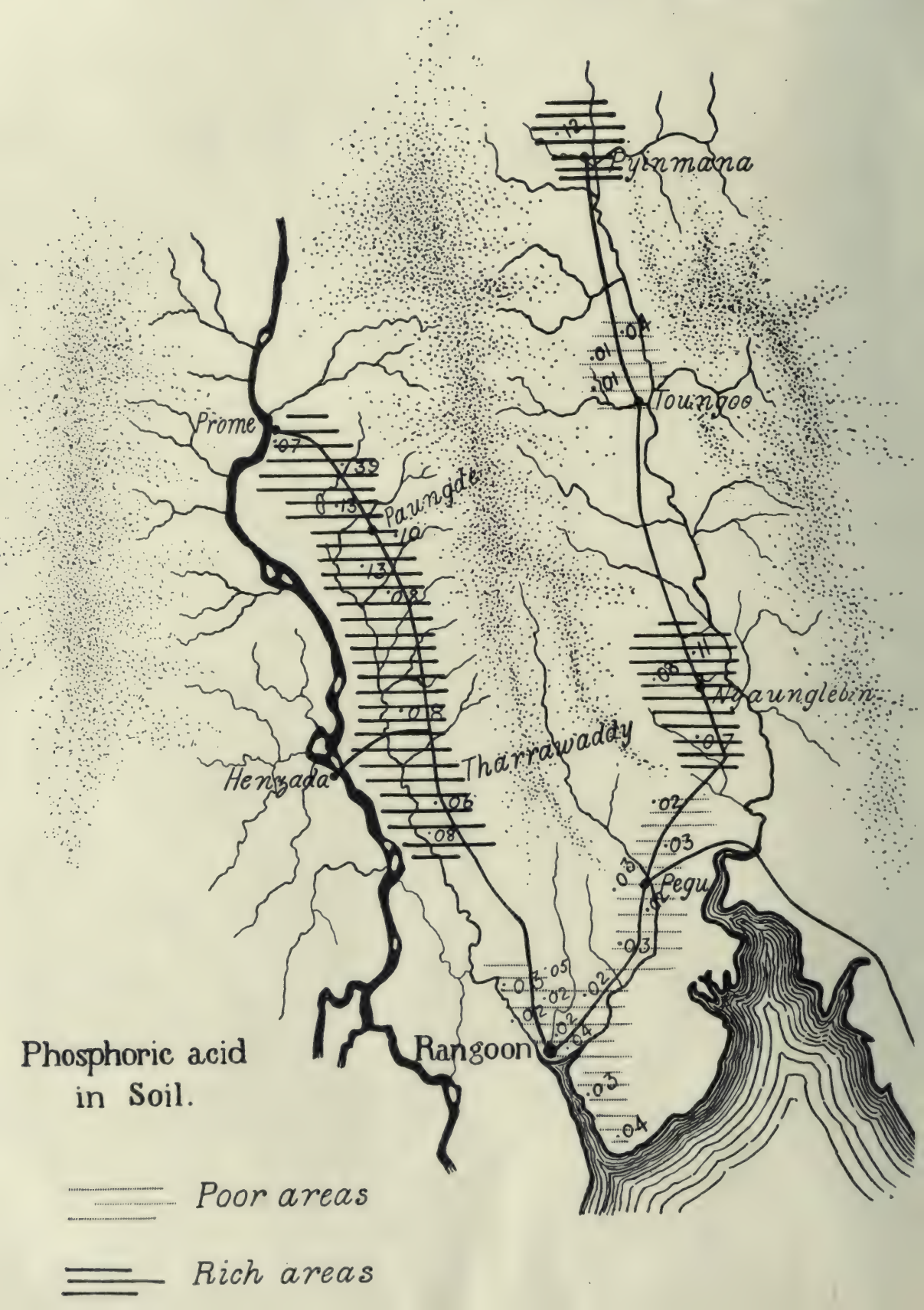
In the third group, two soils, Nos. 20 and 26, containing 0·05 per cent., are found to be rich, whilst one containing 0·04 per cent. is poor.

In the last group the evidence is somewhat slender. These soils should probably contain not less than 0·03 per cent. phosphoric acid to give satisfactory crops.

We have not got a perfect sequence of figures in any case to come to a final conclusion, but taking all the evidence together it appears that the denser soils require a higher percentage of phosphoric acid than the more open soils.

For the denser soils probably 0·07 per cent. is the lowest safe figure. For sandy loams 0·05 per cent. is seen to be sufficient, whilst very sandy soils may be able to produce full crops with a still smaller supply. Insein B with 0·02 per cent. phosphoric acid is able to produce a full crop, but the crop is decidedly deficient in phosphoric acid. The phosphoric acid content

Scale, 32 miles=1 inch.



required to produce satisfactory paddy crops even in the case of heavy soils (which appear to demand decidedly more than the lighter soils) is found to be somewhat lower than the amount usually considered necessary. The limiting quantities of phosphoric acid here given refer to pot cultures. The limit for field cultures might be slightly different but we can scarcely conceive that they would be higher.

Mr. W. A. Davis (*The Agricultural Journal of India*, Science Congress Number, 1917) gives available phosphoric acid data from typical calcareous Gangetic soils. Some of these figures are extremely low even compared with our low figures.

The total phosphoric acid of these soils is however not given, and therefore a true comparison with our results cannot be made.

Rawson (also quoted in the same paper) gives total and available phosphoric acid figures for some Gangetic soils, which, according to the standards just established for the Lower Burma soils, would be considered decidedly high. Experimental manuring has, however, shown that the soils are deficient in phosphoric acid. These results prove that the Lower Burma soils require less phosphoric acid to produce satisfactory crops than is needed by the Gangetic soils.

7. Distribution of phosphoric acid in the soils of Lower Burma.

With the aid of Table VI, a soil map has been prepared showing distribution of soils rich and poor in phosphoric acid respectively. We see from this map that there is a large area of soils rich in phosphoric acid in the Hlaing valley along the Rangoon-Prome line.

Another rich area occurs between Nyaunglebin and Daiku. Its extent has not been determined.

Much further north we strike a rich soil at Pyinmana, but between these two last areas there lies a region of poor soils in the neighbourhood of Toungoo.

The most extensive area of poor soils lies within Pegu, Hanthawaddy and Insein districts.

8. Soil nitrogen supply.

To elucidate the contradictory results of manuring with super alone, some points regarding nitrogen supply must be considered.

TABLE VII.

Showing association of high nitrogen with low phosphoric acid.

Serial No.	Name of soil	Nitrogen	Phosphoric acid	Class
1	Dabein B	0·084	0·02	Poor
2	Hlegu B	0·076	0·05	Rich
3	Thongwa	0·119	0·04	Poor
4	Sitkwin	0·076	0·08	Rich
5	Kyauktan	0·105	0·03	Poor
6	Thonze	0·081	0·06	Rich
7	Hlegu D	0·116	0·02	Poor
8	Tantabin	0·057	0·09	Rich

The above table shows that in certain cases low phosphoric acid is associated with high nitrogen. We have a collection of soils which are alternately poor and rich in phosphoric acid content. Some additional less typical soils will be seen in the full Table A. The peculiarity here indicated is by no means universal amongst the Lower Burma soils, but the number of cases in which it is seen is sufficient to be striking.

The point to which attention is called is that the soils relatively rich in phosphoric acid are deficient in nitrogen, whilst those which are poor in phosphoric acid are richer in nitrogen.

This indicates certainly that with soils poor in phosphoric acid the nitrogen is not so completely utilized.

Such a result must be due to one or more of the following causes :—

(1) Poor plant growth through lack of phosphoric acid.

(2) More resistant character of the organic matter in these soils.

(3) Biological environment unfavourable to disintegration of organic matter.

An important field of enquiry is indicated by this phenomenon.

The addition of phosphatic manures to these soils has been shown in our pot cultures to have no immediate effect on ammonification. This is an important result from a practical point of view. There can be little doubt, however, from the evidence of the richer soils, that in time addition of phosphoric acid would improve the ammonification in the poorer soils.

Before leaving this table it is perhaps desirable to point out that the pot cultures showed nitrogen to be effective on the even numbers which are low in nitrogen and not effective on the odd numbers which are richer in nitrogen. It might be assumed from this that the pot cultures merely showed lack of nitrogen and have nothing to do with the phosphatic requirements.

That this is quite wrong is proved by the following evidence :—

(*a*) The soils rich in phosphoric acid whether they be poor or rich in nitrogen are found to behave identically with nitrogen manuring.

(*b*) The initial effect of nitrogen in the soils of Table VI is not inversely proportional to the amount of nitrogen they contain, but is zero when phosphoric acid is lacking and is perfect when phosphoric acid is sufficient.

(*c*) The plants grown on poor soils are seriously deficient in phosphoric acid.

(*d*) The powerful effect of adding phosphoric acid to nitrogen in the case of soils poor in phosphoric acid and the corresponding absence of effect with soils well supplied with phosphoric acid.

Considering the nitrogen figures of all the soils we see that a few are decidedly poor. Most are moderately well supplied and some may be considered rich in nitrogen. The soil nitrogen is made available to the plant through biochemical processes which are certainly not very effective in our pot cultures, although one month was allowed for the pots to develop their normal bacterial flora before the plants were put in, and the previous treatment of drying and crushing to which these soils were submitted has been shown in a large number of experiments carried out in the laboratory here to improve ammonification.

The inadequacy of available nitrogen in these soils is shown by the great crop increases produced by nitrogen manuring, especially if shortage of phosphoric acid is at the same time made good.

This lack of available nitrogen is doubtless the explanation of the negative and contradictory results with superphosphate manuring alone.

The great advantage of ammonium sulphate in this enquiry will now be evident. By it we ensure a supply of nitrogen quite independent of biochemical activity, and the phosphoric acid of the soil or manure can then come into operation.

Without at present attempting to assign a reason for the fact, we have to conclude that all these soils, more especially those poor in phosphoric acid, are not liberating nitrogen plant food readily.

The pot cultures have shown that without readily available nitrogen phosphatic manuring is useless.

The soils are at least moderately well supplied with nitrogen, and it would suffice if only it could be made more available. There is one method of

making the soil nitrogen available for paddy, and that is by converting it into green manure.

This actually happens every year all over Lower Burma. Before the fields can be ploughed they are covered with vegetation. If this green manure is sufficient in quantity the poor soils may still be able to give immediate effects with phosphatic manuring. The question is of considerable importance to the agriculture of the province.

III. SUMMARY.

(1) By using ammonium sulphate as a source of nitrogen which is not dependent upon the biochemical activity of the soil, and thus removing a serious complication, pot cultures have yielded striking figures which clearly differentiate soils lacking in phosphoric acid from those which are well supplied with phosphoric acid.

(2) The phosphoric acid content necessary to produce satisfactory crops has been shown to be somewhat lower than the amount usually considered necessary.

(3) The lack of phosphoric acid is by no means general all over Lower Burma. It is serious only within definite areas. The available phosphate supplies of the province will therefore meet the want more easily than it was feared might be the case.

(4) The soil nitrogen in these soils is far from readily available. This seems to be more particularly true of the soils poor in phosphoric acid.

The lack of available nitrogen is so serious that phosphoric acid manuring cannot increase crop yields on soils poor in phosphoric acid.

(5) It is possible that the vegetation produced during the early rains is sufficient to act as a green manure, thus making the nitrogen more readily available. If so, phosphoric acid manuring will give immediate crop increase on such soils. This question seems to be of special importance.

APPENDIX.

TABLE A.

Soil analyses.

1915.

Name of soil	Yedashe A	Yedashe B	Kyungon A	Kyungon B	Daiku	Pyinbongyi A	Pyinbongyi B	Insein A	Insein B	Tantabin A	Tantabin B
Insoluble residue	54·30	81·66	84·37	84·20	58·10	71·00	84·65	69·48	89·88	77·92	77·24
Soluble silica	17·91	8·32	6·08	6·56	16·41	11·94	5·51	12·45	3·91	8·38	8·51
Ferric oxide (Fe_2O_3)	5·30	1·85	1·81	1·94	5·66	2·42	1·63	3·21	0·55	3·79	3·65
Alumina (Al_2O_3)	13·46	4·67	4·65	4·11	11·43	8·59	4·51	8·50	2·18	5·93	5·88
Lime (CaO)	0·35	0·14	0·12	0·12	0·20	0·06	0·05	0·07	0·04	0·30	0·28
Magnesia (MgO)	0·50	0·17	0·09	0·09	0·40	0·08	0·05	0·15	0·03	0·35	0·46
Potash (K_2O)	0·76	0·37	0·24	0·21	0·80	0·41	0·24	0·60	0·14	0·31	0·46
Soda (Na_2O)	0·30	0·15	0·18	0·20	0·43	0·22	0·18	0·29	0·19	0·26	0·29
Sulphuric acid (SO_3)	0·06	0·04	0·03	0·05	0·06	0·05	0·07	0·10	0·03	0·06	0·07
Phosphoric acid (P_2O_5)	0·01	0·01	0·01	0·01	0·07	0·03	0·02	0·02	0·02	0·09	0·09
Carbon-dioxide (CO_2)	0·00	0·00	0·00	0·00	0·01	0·01	0·01	0·01	0·01	0·00	0·01
Organic matter + Combined water	7·02	2·62	2·42	2·51	6·43	5·19	3·08	5·57	3·02	2·61	3·06
Organic carbon											
Organic nitrogen	0·0992	0·0525	0·0514	0·0654	0·1132	0·0887	0·0677	0·1051	0·1037	0·0514	0·0573
Available phosphoric acid	0·0048	0·0012	0·0009	0·0009	0·0182	0·0057	0·0020	0·0009	0·0016	0·0149	0·0468
Available potash	0·0352	0·0209	0·0066	0·0221	0·0329	0·0161	0·0135	0·0124	0·0134	0·0201	0·0209

TABLE A—*continued.*

1916.

Name of soil	Nyaunglebin A	Nyaunglebin B	Ledaunggan A	Ledaunggan B	Pegu A	Pegu B	Dabein A	Dabein B	Hlegu A	Hlegu B	Hlegu C	Hlegu D
Insoluble residue	57·94	58·14	52·36	51·88	83·92	79·25	66 85	71 86	49·66	75·04	85·35	71·90
Soluble silica	18·97	15·97	17·05	16·15	7·07	7·99	12·99	10·63	20·96	10·33	6·25	12·47
Ferric oxide (Fe_2O_3)	7·63	6·22	7·06	6·91	1·26	2·30	4·98	4·15	4·94	4·23	0·63	1·12
Alumina (Al_2O_3)	14·10	11·44	13·05	14·33	4·28	6·31	9·64	7·84	14·06	6·32	4·53	8·51
Lime (CaO)	0·25	0·25	0·17	0·26	0·06	0·13	0·16	0·18	0·25	0·21	0·07	0·08
Magnesia (MgO)	1·25	0·57	0·77	0·80	0·05	0·07	0·08	0·11	0·49	0·57	0·04	0·11
Potash (K_2O)	0·96	0·73	0·82	1·03	0·23	0·34	0·51	0·51	0·74	0·24	0·17	0·34
Soda (Na_2O)	0·35	0·27	0·31	0·39	0·16	0·23	0·28	0·19	0·52	0·29	0·16	0·21
Sulphuric acid (SO_3)	0·05	0·04	0·05	0·07	0·05	0 07	0·06	0·05	0·08	0·04	0·04	0·05
Phosphoric acid (P_2O_5)	0·08	0·11	0·03	0·04	0·03	0·02	0·03	0·02	0·07	0·05	0·02	0·02
Carbon-dioxide (CO_2)	0·10	0·08	0·09	0·04	0·03	0·06	0·05	0·02	0·08	0·06	0·04	0·03
Organic matter + Combined water ...	8·32	6·18	8·24	8·10	2·86	3·23	4·37	4·44	8·15	2·62	2·70	5·16
Organic carbon	0·6103	0·2853	0·7360	1·4600	0·7370	0·7160	0·7700	0·8730	1·1607	0·7110	0·8800	1·3936
Organic nitrogen	0·1156	0·0794	0·1284	0·1331	0·0724	0·0607	0·1074	0·0841	0·1278	0·0755	0·0871	0·1162
Available phosphoric acid	0·0073	0·0212	0·0017	0·0019	0·0097	0·0030	0·0011	0·0010	0·0044	0·0045	0·0013	0·0007
Available potash	0·0147	0·0375	0·0070	0·0066	0·0039	0·0112	0·0139	0·0155	0·0178	0·0201	0·0128	0·0064

TABLE A—*concluded.*

1917.

Name of soil	Nattalin	Zigon	Sitkwin	Thonze	Prome	Hmawza	Thegon	Paungde	Kyauktan	Thongwa	Thilawa	Kayan
Insoluble residue	60·32	55·19	68·84	75·51	58·46	78·73	55·80	51·99	73·00	69·99	64·75	75·14
Soluble silica	15·10	16·39	10·03	9·38	15·40	8·94	15·32	16·79	9·95	10·24	11·62	8·76
Ferric oxide (Fe_2O_3)	7·27	7·82	4·55	4·33	6·61	2·60	7·03	7·70	4·07	5·18	6·03	3·36
Alumina (Al_2O_3)	9·95	11·90	6·30	6·15	11·10	4·79	11·45	13·48	7·21	8·36	9·76	7·02
Lime (CaO)	0·39	0·23	0·24	0·20	0·26	0·15	0·35	0·55	0·17	0·22	0·12	0·26
Magnesia (MgO)	1·12	1·05	0·94	0·78	0·80	0·07	1·09	0·13	0·29	0·30	0·17	0 64
Potash (K_2O)	0·65	0·96	0·46	0·45	0·91	0·36	0·93	1·02	0·39	0·39	0·41	0·42
Soda (Na_2O)	0·10	0·04	0·05	0·06	0·77	0·45	0·53	0·58	0·16	0·14	0·12	0·22
Salphuric acid (SO_3)	0·08	0·05	0·03	0·05	0·06	0·07	0·07	0·08	0·07	0·05	0·10	0·06
Phosphoric acid (P_2O_5)	0·13	0·08	0·08	0·06	0·07	0·39	0·11	0·10	0·03	0·04	0·03	0·05
Carbon-dioxide (CO_2)	0·01	0·02	0·02	0·02	0 01	0·02	0·02	0·02	0·01	0·01	0·00	0·01
Organic matter + Combined water	4·88	6·27	8·46	3·01	5·55	3·43	7·30	7·56	4·65	5·08	6·89	4·06
Organic carbon	1·4471	1·2447	0·8149	0·7204	0·6474	0·7549	1·2992	1·0374	1·1830	1·2049	1·8502	0·8111
Organic nitrogen	0·1684	0·1394	0·0755	0·0813	0·0784	0·0755	0·1423	0·1307	0·1045	0·1191	0·1162	0·0813
Available phosphoric acid	0·0373	0·0083	0·0304	0·0134	0·0038	0·2305	0·0279	0·0150	0·0012	0·0057	0·0023	0·0189
Available potash	0·0108	0·0093	0·0058	0·0077	0·0128	0·0100	0·0101	0·0070	0·0101	0·0070	0·0070	0·0077

TABLE B.

Showing pot culture crop yields.

Year	Soil	Average weight of seeds				Average weight of straw			
		Blank	Super-phosphate	Am_2SO_4	Am_2SO_4 + Super-phosphate	Blank	Super-phosphate	Am_2SO_4	Am_2SO_4 + Super-phosphate
1915	Kyungon B	29·7(1·2)	.....	39·0(2·5)	42·0(4·0)	40·0(2·0)	.....	71·0(3·8)	104·0(11·0)
	Daiku	33·1(3·4)	.....	54·2(3·7)	57·0(4·5)	61·2(4·5)	.....	125·0(7·8)	135·0(4·8)
	Pyinbongyi A	51·8(2·8)	.....	63·2(3·2)	62·2(2·6)	78·5(2·1)	.....	108·5(8·5)	112·0(5·2)
	Pyinbongyi B	35·7(1·0)	.....	40·0(1·2)	51·5(4·2)	57·5(1·6)	.....	81·0(3·8)	114·0(1·5)
	Insein A	20·7(1·5)	.....	29·2(0·7)	40·0(1·5)	27·5(1·5)	.....	46·0(1·8)	101·0(1·0)
	Insein B	44·2(3·2)	.....	55·0(2·2)	49·0(7·8)	96·0(1·9)	.....	116·0(10·2)	115·5(8·2)
	Tantabin A	29·5(3·1)	.....	52·0(4·5)	51·2(3·8)	33·0(3·0)	.....	97·5(10·8)	102·0(6·8)
1916	Nyaunglebin A	6·0(1·2)	6·0(0·4)	30·0(2·4)	33·0(2·6)	10·0(0·8)	10·0(0·25)	74·0(1·25)	83·0(3·25)
	Nyaunglebin B	9·0(0·8)	8·4(0·4)	34·6(2·6)	35·0(1·8)	12·6(0·6)	12·6(1·4)	86·0(6·2)	88·5(2·5)
	Dabein A	13·5(1·5)	10·6(1·6)	29·4(3·9)	33·0(1·9)	17·4(1·1)	14·0(1·5)	35·5(5·8)	81·5(6·0)
	Dabein B	14·4(3·3)	12·5(0·25)	29·6(1·3)	39·0(2·2)	19·5(3·8)	16·0(0·9)	39·5(4·8)	88·0(3·2)
	Pegu A	21·0(1·8)	23·0(1·9)	38·0(1·6)	39·6(2·6)	30·5(2·0)	34·0(2·0)	71·0(1·8)	74·5(5·2)
	Pegu B	20·6(2·1)	20·4(1·1)	43·0(3·6)	39·0(2·8)	25·0(3·2)	26·5(1·8)	61·0(2·5)	89·5(5·5)
	Ledaunggan A	7·6(1·1)	7·0(0·6)	30·0(2·2)	35·4(1·7)	11·0(1·2)	9·6(0·9)	35·0(0·0)	68·0(3·0)
	Ledaunggan B	12·4(1·4)	12·6(0·9)	30·0(2·0)	35·0(1·5)	20·6(2·2)	21·0(2·5)	35·0(4·0)	75·0(5·75)
	Hlegu A	10·6(2·0)	8·6(1·1)	19·5(7·8)	34·0(7·6)	16·0(2·8)	13·5(1·5)	79·0(4·8)	84·0(4·8)
	Hlegu B	22·0(1·8)	21·6(1·9)	50·0(0·8)	45·0(1·6)	39·5(2·5)	42·0(2·8)	86·5(3·5)	91·5(2·0)
	Hlegu C	17·0(1·8)	16·4(1·1)	27·0(2·8)	42·5(3·0)	35·5(3·0)	42·0(2·8)	39·0(4·8)	69·0(9·5)
	Hlegu D	22·0(1·6)	28·0(1·2)	32·0(7·8)	43·0(3·8)	37·0(3·5)	45·5(1·5)	61·5(2·2)	75·0(2·2)
1917	Kyauktan	30·0(1·8)	35·5(1·2)	52·0(4·5)	60·5(2·2)	42·5(1·5)	53·5(2·0)	80·5(7·2)	112·5(2·5)
	Thilawa	25·5(2·2)	39·0(1·5)	35·0(4·0)	54·0(3·8)	37·0(0·5)	58·0(1·2)	42·0(2·8)	102·0(1·8)
	Thongwa	32·0(1·8)	33·0(2·5)	59·0(6·8)	53·0(2·8)	45·5(3·0)	52·0(2·8)	95·0(5·0)	106·0(6·5)
	Kayan	30·5(2·2)	30·0(3·2)	51·0(2·5)	50·0(2·2)	44·0(2·0)	45·5(2·8)	107·5(3·0)	98·0(5·2)
	Prome	15·0(2·2)	18·5(2·5)	41·0(1·2)	42·0(0·5)	21·0(2·8)	26·0(1·8)	89·0(4·8)	92·0(3·8)
	Thegon	44·0(4·2)	48·0(1·8)	73·0(7·2)	70·5 5·0)	66·0(6·2)	73·0(4 0)	137·0(7·2)	127·0(4·8)
	Hmawza	43·0(3·5)	45·5(0·8)	66·0(0·8)	69·0(4·0)	54·0(6·2)	63·0(2·2)	123·0(4·8)	126·5(8·0)
	Paungde	23·0(3·8)	23·0(1·8)	45·0(2·8)	39·0(4 0)	33·5(3·5)	33·0(2·0)	95·0(4·5)	92·0(5·5)
	Zigon	29·0(2·5)	26·0(1·0)	48·5	44·0	41·0(2·0)	39·0(0·75)	71·0	68·5
	Nattalin	48·0(3·5)	47·5(7·0)	70·0(2·8)	68·0(2·8)	75·0(4·8)	79·0(6·0)	143·5(4·0)	142·5(2·8)
	Sitkwin	32·0(1·2)	32·0(1·2)	53·0(4·8)	59·0(1·5)	42·0(2·5)	42·0(1·0)	101·0(3·5)	99·0(1·8)
	Thonze	38·5(2·0)	39·0(1·8)	62·0(2·0)	64·0(3·2)	50·0(1·5)	51·5(1·5)	109·5(3·2)	105·0(3·8)

TABLE C.

Showing initial development of paddy in pot cultures.

Year	Name of soil	Blank	Super-phosphate	Am_2SO_4	Am_2SO_4 + Super-phosphate
1915	Yedashe A	350	.....	754	1,075
	Yedashe B	300	.....	300	910
	Kyungon A	237	.....	250	850
	Kyungon B	300	.....	350	850
	Daik-u	575	.....	1,100	1,248
	Pyinbongyi A	600	.....	600	900
	Pyinbongyi B	400	.....	375	1,054
	Insein A	200	.....	300	900
	Insein B	1,215	.....	1,215	1,215
	Tantabin A	200	.....	900	900
	Tantabin B	468	.....	1,004	1,000
1916	Nyaunglebin A	84	80	294	528
	Nyaunglebin B	114	100	551	550
	Dabein A	76	123	80	484
	Dabein B	72	80	80	441
	Pegu A	180	210	385	400
	Pegu B	68	69	70	380
	Ledaunggan A	64	64	64	240
	Ledaunggan B	85	85	85	242
	Hlegu A	90	90	390	320
	Hlegu B	300	300	383	400
	Hlegu C	120	190	120	238
	Hlegu D	120	280	162	216
1917	Kyauktan	242	504	242	1,053
	Thilawa	294	483	483	910
	Thongwa	529	625	650	1,146
	Kayan	529	598	944	1,146
	Prome	231	231	725	884
	Thegon	792	792	1,320	1,218
	Hmawza	506	300	1,334	1,334
	Paungde	266	266	884	884
	Zigon	462	462	900	1,000
	Nattalin	696	696	1,283	1,595
	Sitkwin	504	504	814	814
	Thonze	529	529	1,092	1,092

NOTE.—This table shows development attained 4 weeks after transplanting. Measurements were made and figures are available for development at regular intervals throughout the period of growth. The inclusion of all these figures would have made the table very cumbersome and they have therefore been excluded. Some idea of the notable difference which occurred during further development may be seen by comparing this table with Table B giving final crop yields.

Table D.

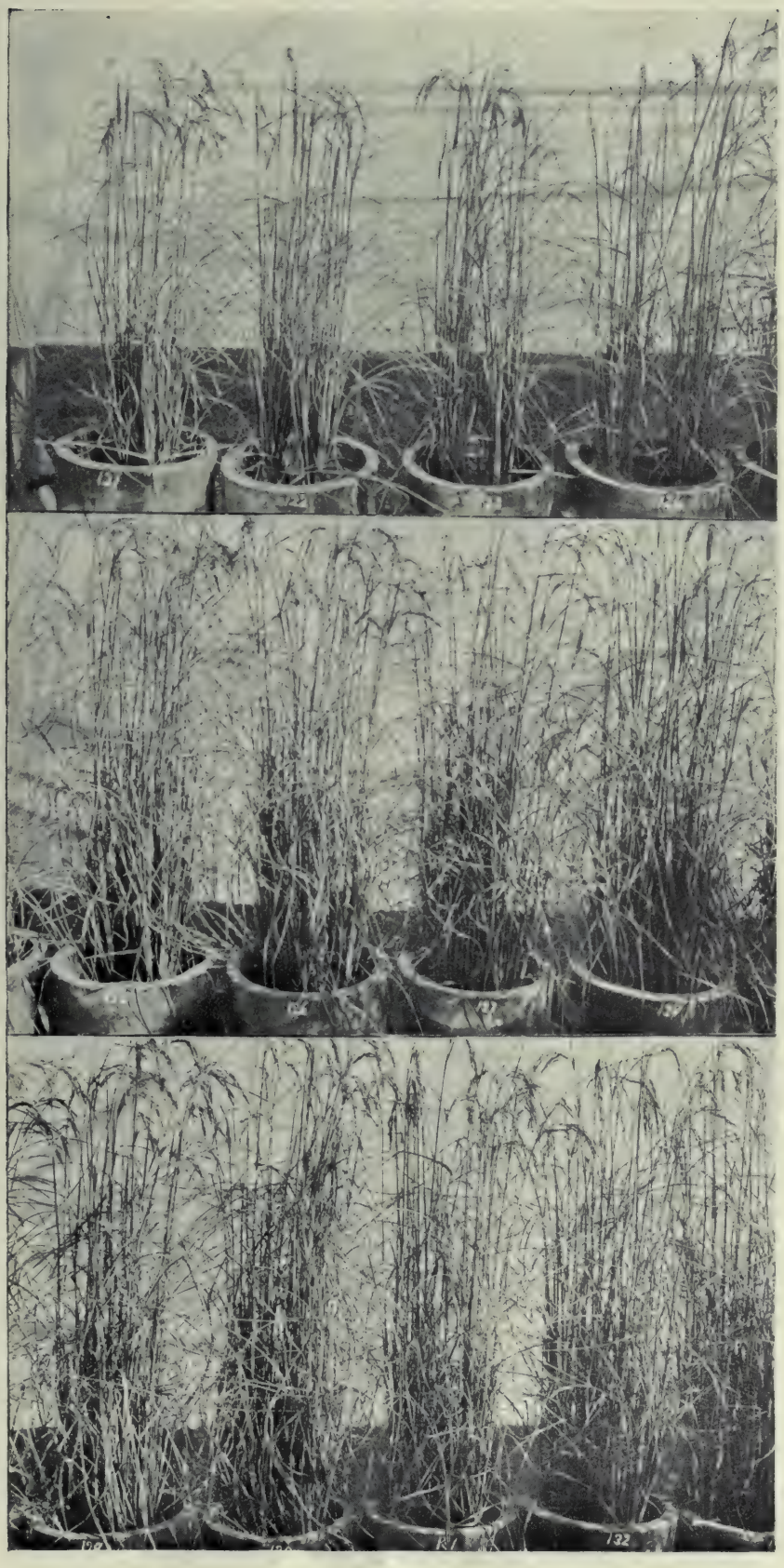
P_2O_5 in straw.

Year	Name of soil	Blank	Super-phosphate	Am_2SO_4	Am_2SO_4 + Super-phosphate
1915	Kyungon B	0·0427	.....	0·0376	0·2035
	Daiku	0·2770	.....	0·3351	0·3249
	Pyinbongyi A	0·2616	.....	0·1419	0·2685
	Pyinbongyi B	0·0479	.....	0·0479	0·2086
	Insein A	0·0239	.....	0·0239	0·1915
	Insein B	0·1864	.....	0·1590	0·3659
	Tantabin A	0·3523	.....	0·3557	0·3506
1916	Nyaunglebin A	0·2982	0·3386	0·3502	0·3186
	Nyaunglebin B	0·3972	0·3907	0·3437	0·3774
	Dabein A	0·0850	0·3527	0·0330	0·2609
	Dabein B	0·1200	0·3442	0·0486	0·2009
	Pegu A	0·4810	0·4754	0·4229	0·4053
	Pegu B	0·3759	0·4116	0·1598	0·3603
	Ledaunggan A	0·1101	0·2994	0·0393	0·2095
	Ledaunggan B	0·0809	0·3134	0·0291	0·2346
	Hlegu A	0·3805	0·3531	0·5198	0·4634
	Hlegu B	0·5327	0·4857	0·4438	0·4651
	Hlegu C	0·0992	0·4620	0·0342	0·2117
	Hlegu D	0·0641	0·4147	0·0530	0·1402
1917	Kyauktan	0·0887	0·3388	0·0661	0·2604
	Thilawa	0·0486	0·2308	0·0271	0·1641
	Thongwa	0·3260	0·3175	0·1803	0·3667
	Kayan	0·4226	0·3474	0·2986	0·4603
	Prome	0·3218	0·3069	0·3448	0·3693
	Thegon	0·4113	0·3979	0·4132	0·4115
	Hmawza	0·4518	0·5035	0·4074	0·4727
	Paungde	0·3569	0·3964	0·4347	0·4134
	Zigon	0·3508	0·3416	0·4597	0·5093
	Nattalin	0·4077	0·4413	0·4258	0·3973
	Sitkwin	0·5719	0·5051	0·4151	0·5051
	Thonze	0·4198	0·4665	0·3846	0·4393

DAIKU SOIL.

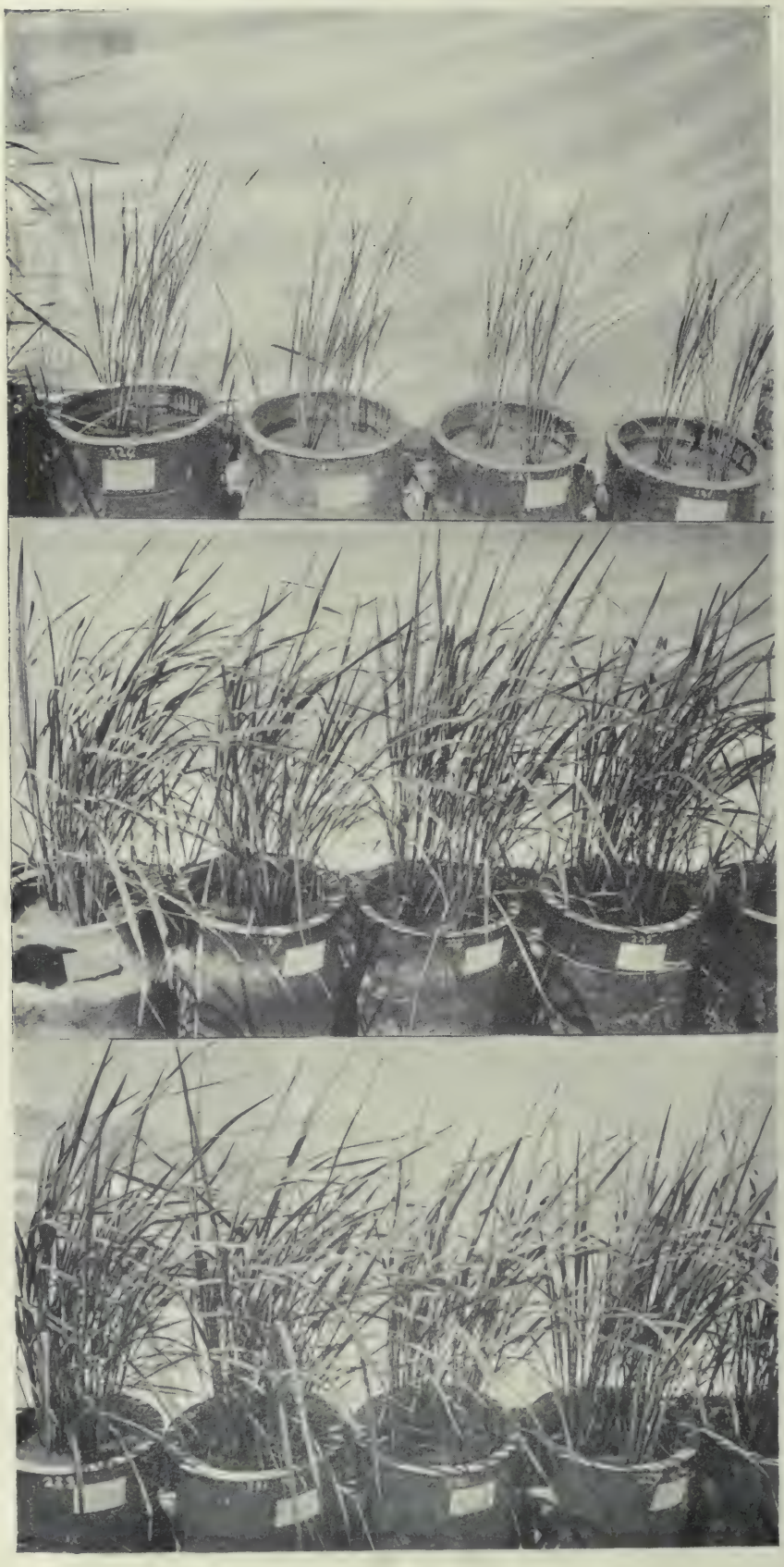
Growth of 4 weeks.

DAIKU SOIL.



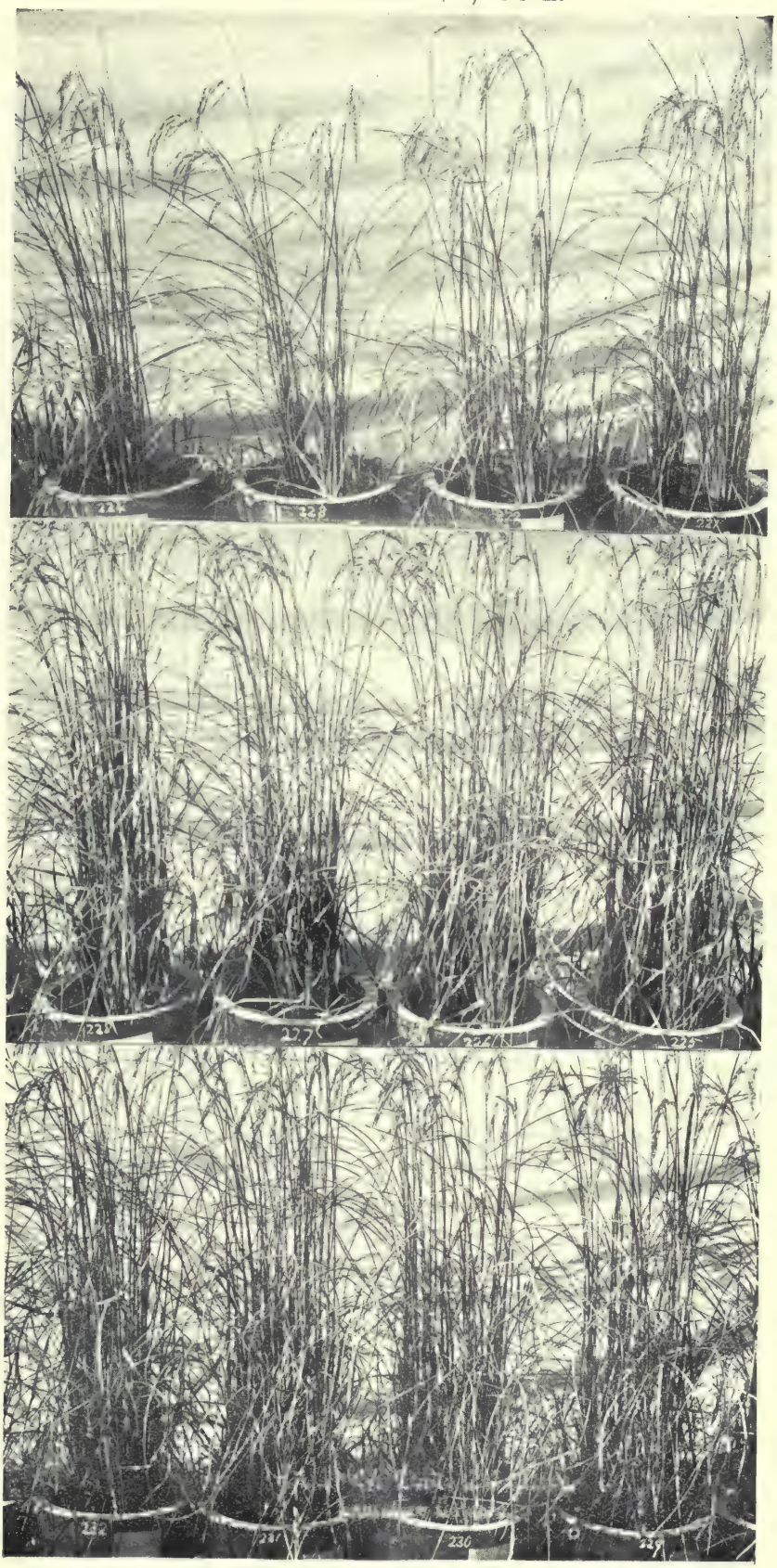
Growth of 21 weeks.

TANTABIN (A) SOIL.



Growth of 4 weeks.

TANTABIN (A) SOIL.

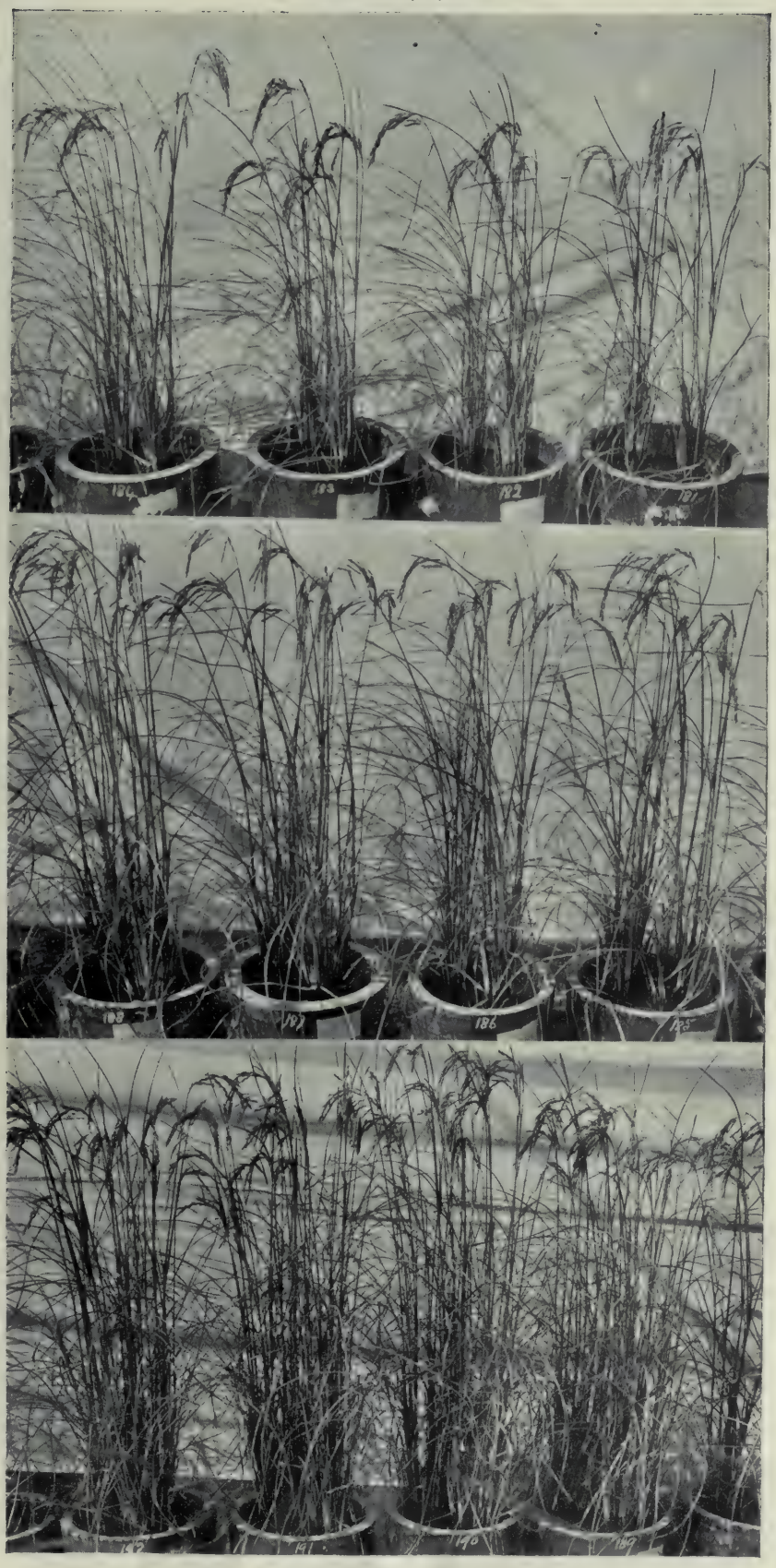


Growth of 21 weeks.

INSEIN (A) SOIL.

Growth of 4 weeks.

INSEIN (A) SOIL.



Growth of 21 weeks.

PYINBONGYI (B) SOIL.

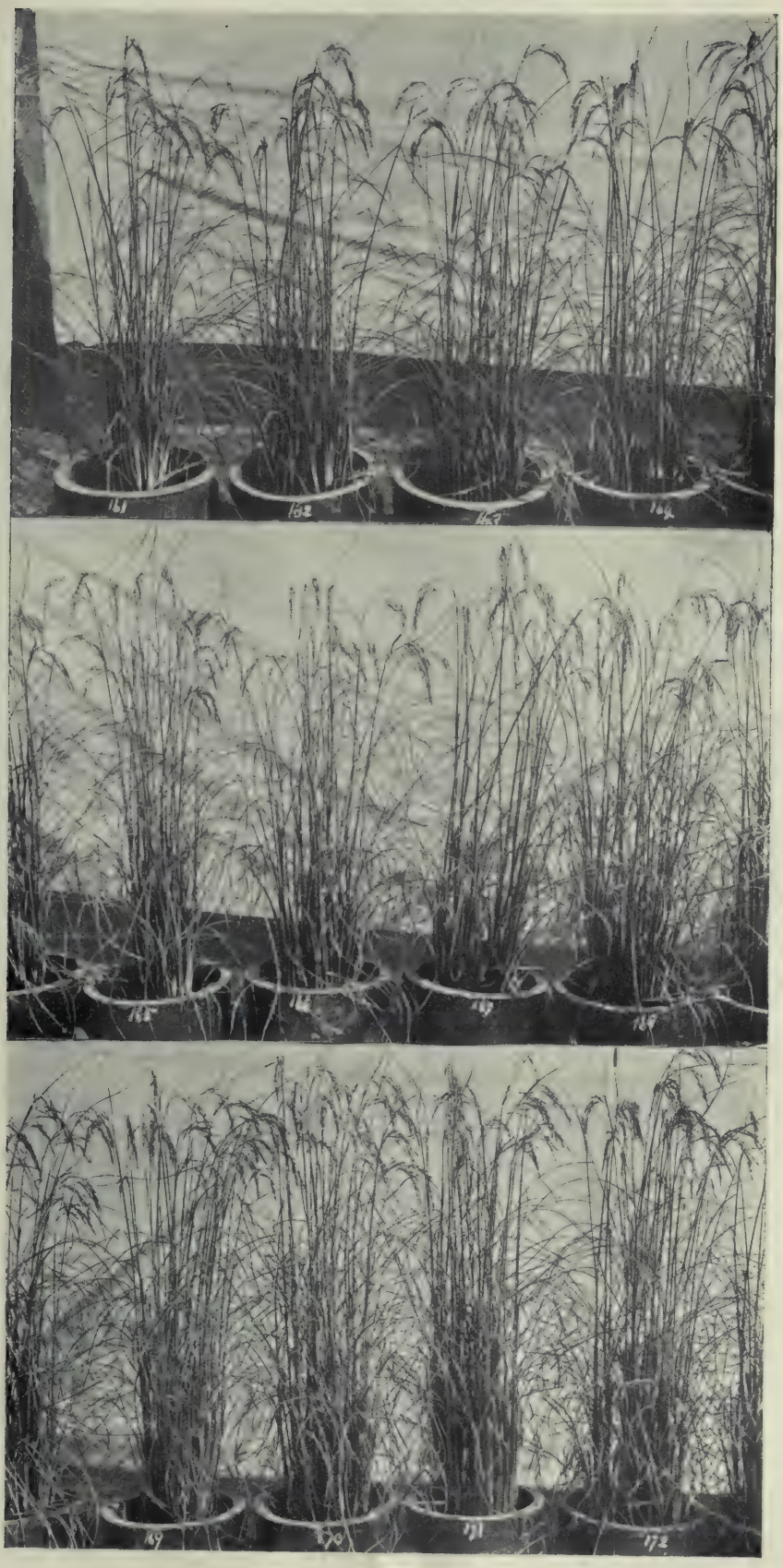
Growth of 4 weeks.

PYINBONGYI (B) SOIL.

NO MANURE

NITROGEN

PHOSPHORUS AND NITROGEN



Growth of 21 weeks.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA.

TO BE HAD FROM

THE OFFICE OF THE AGRICULTURAL ADVISER TO THE GOVERNMENT OF INDIA, PUSA, BIHAR,
and from the following Agents :—

(1) THACKER, SPINK & CO., CALCUTTA.
(2) W. NEWMAN & CO., CALCUTTA.
(3) RAI M. C. SARKAR BAHADUR & SONS, CALCUTTA.
(4) HIGGINBOTHAMS, LTD., MADRAS.
(5) THOMPSON & CO., MADRAS.
(6) D. B. TARAPOREVALA, SONS & CO., BOMBAY.
(7) THACKER & CO., LTD., BOMBAY.
(8) SUNDER PANDURANG, BOMBAY.
(9) RAI SAHIB M. GULAB SINGH & SONS, LAHORE.
(10) MANAGER, EDUCATIONAL BOOK DEPOT, NAGPUR.

A complete list of the publications of the Imperial Department of Agriculture in India can be obtained on application from the Agricultural Adviser to the Government of India, Pusa, Bihar, or from any of the above-mentioned Agents.

These publications are :—

1. The *Agricultural Journal of India.* A Quarterly Journal dealing with subjects connected with agricultural economics, field and garden crops, economic plants and fruits, soils, manures, methods of cultivation, irrigation, climatic conditions, insect pests, fungus diseases, co-operative credit, agricultural cattle, farm implements, and other agricultural matters in India. Illustrations, including coloured plates, form a prominent feature of the Journal. It is edited by the Agricultural Adviser to the Government of India. *Annual Subscription*, Rs. 6 or 8*s.* 6*d.*, including postage. Single copy, Rs. 2 or 3*s.*
2. Scientific Reports of the Agricultural Research Institute, Pusa (including the Report of the Imperial Cotton Specialist).
3. Annual Report on the Progress of Agriculture in India.
4. Proceedings of the Board of Agriculture in India.
5. Proceedings of Sectional Meetings of the Board of Agriculture.
6. Memoirs of the Imperial Department of Agriculture in India :
   (a) Botanical Series.
   (b) Chemical Series.
   (c) Entomological Series.
   (d) Bacteriological Series.
   (e) Veterinary Series.
7. Bulletins issued by the Agricultural Research Institute, Pusa.
8. Books.

The following are the publications of the last two years :—

Scientific Reports of the Agricultural Research Institute and College, Pusa (including the Report of the Imperial Cotton Specialist), for the year 1916-17. Price, As. 9 or 10*d.*

AGRICULTURAL PUBLICATIONS.—(*Concld.*)

Scientific Reports of the Agricultural Research Institute, Pusa (including the Report of the Imperial Cotton Specialist), for the year 1917-18. Price, R. 1-4 or 2*s.*

Report on the Progress of Agriculture in India for the year 1916-17. Price, As. 12 or 1*s.* 1*d.*

Report on the Progress of Agriculture in India for the year 1917-18. Price, R. 1-8 or 2*s.* 3*d.*

Proceedings of the Board of Agriculture in India, held at Poona on the 10th December, 1917, and following days (with Appendices). Price, As. 13 or 1*s.* 3*d.*

Proceedings of the Second Meeting of Mycological Workers in India, held at Pusa on the 20th February, 1919, and following days. (*In the press.*)

Proceedings of the First Meeting of Veterinary Officers in India, held at Lahore on the 24th March, 1919, and following days (with Appendices). (*In the press.*)

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA.

BOTANICAL SERIES.

Vol. IX, No. I. The Dissemination of Parasitic Fungi and International Legislation, by E. J. BUTLER, M.B., F.L.S. Price, R. 1-4 or 2*s.*

Vol. IX, No. II. The Inheritance of Characters in Rice, I, by F. R. PARNELL, B.A.; G. N. RANGASWAMI AYYANGAR, B.A.; and K. RAMIAH, L.Ag. Price, R. 1-8 or 2*s.*

Vol. IX, No. III. *Orobanche* as a Parasite in Bihar, by F. J. F. SHAW, D.Sc., A.R.C.S., F.L.S. Price, R. 1 or 1*s.* 6*d.*

Vol. IX, No. IV. Studies in Indian Sugarcanes, No. 3. The Classification of Indian Canes with special reference to the Saretha and Sunnabile Groups, by C. A. BARBER, Sc.D. Price, Rs. 2-4 or 3*s.*

Vol. IX, No. V. *Phytophthora Meadii* n. sp. on *Hevea brasiliensis*, by W. MCRAE, M.A., B.Sc., F.L.S. Price, R. 1-4 or 2*s.*

Vol. X, No. I. The Rice Worm (*Tylenchus angustus*) and its Control, by E. J. BUTLER, M.B., F.L.S. Price, R. 1-4 or 2*s.*

Vol. X, No. II. Studies in Indian Sugarcanes, No. 4. Tillering or Underground Branching, by C. A. BARBER, C.I.E., Sc.D., F.L.S. Price, Rs. 4-4 or 7*s.*

Vol. X, No. III. Studies in Indian Sugarcanes, No. 5. On testing the suitability of sugarcane varieties for different localities, by a system of measurements. Periodicity in the growth of the sugarcane, by C. A. BARBER, C.I.E., Sc.D., F.L.S. Price, R. 1-12 or 3*s.*

CHEMICAL SERIES.

Vol. V, No. II. "Heart Damage" in Baled Jute, by R. S. FINLOW, B.Sc., F.I.C., F.C.S. Price, R. 1 or 1*s.* 6*d.*

Vol. V, No. III. Experiments on the Improvement of the Date Palm Sugar Industry in Bengal, by HAROLD E. ANNETT, B.Sc., F.I.C.; GOSTA BEHARI PAL, M.Sc.; and INDU BHUSHAN CHATTERJEE, L.Ag. Price, R. 1 or 1*s.* 6*d.*

Vol. V, No. IV. Cholam (*A. Sorghum*) as a Substitute for Barley in Malting Operations, by B. VISWANATH, T. LAKSHMANA ROW, B.A., and P. A. RAGHUNATHASWAMI AYYANGAR, Dip. Ag. Price, As. 12 or 1*s.*

Vol. V, No. V. The Phosphate Requirements of some Lower Burma Paddy Soils, by F. J. WARTH, M.Sc., B.Sc., and Maung Po Shin. Price R. 1-12 or 3*s.* 3*d.*

Vol. V, No. VI. Absorption of Lime by Soils, by F. J. WARTH, M.Sc., B.Sc., and MAUNG PO SAW. (*In the press.*)

ENTOMOLOGICAL SERIES.

Vol. V, No. II. Indian Sugarcane Leaf-hopper (*Pyrilla aberrans*, Kirby), by C. S. MISRA, B.A. Price, Rs. 2 or 3*s.*

Vol. V, No. III. Report on a Collection of Termites from India, by KARIN and NILS HOLMGREN, Högskolas Zootomiska Institut, Stockholm, translated by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S. Price, R. 1 or 1*s.* 6*d.*

Vol. V, No. IV. On a Collection of Sphecoidea sent by the Agricultural Research Institute, Pusa, Bihar, by ROWLAND E. TURNER, F.Z.S., F.E.S. Price, As. 12 or 1*s.*

BACTERIOLOGICAL SERIES.

Vol. I, No. VII. A Bacterial Disease of Wheat in the Punjab, by C. M. HUTCHINSON, B.A. Price, As. 12 or 1*s.*

VETERINARY SERIES.

Vol. II, No. VIII. *Kumri*: Combined Diffuse Sclerosis and Central Poliomyelitis of Horses, by G. H. K. MACALISTER, M.A., M.D., D.P.H. Price, R. 1-8 or 2*s.* 6*d.*

Vol. III, No. I. The Vitality of the Rinderpest Virus outside the Animal Body under Natural Conditions, by A. W. SHILSTON, M.R.C.V.S. Price, As. 12 or 1*s.*

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA.

No. 69. Sugar and the Sugarcane in the Gurdaspur District, by J. H. BARNES, B.Sc., F.I.C., F.C.S. Price, As. 14 or 1*s.* 3*d.*

No. 70. The Composition of some Indian Feeding Stuffs, by J. N. SEN, M.A., F.C.S. Price, As. 10 or 1*s.*

No. 71. Water Hyacinth (*Eichornia crassipes*): Its value as a Fertilizer, by R. S. FINLOW, B.Sc., F.I.C., and K. MCLEAN, B.Sc. Price, As. 5 or 6*d.* (*Out of print.*)

No. 72. A Note on Jhooling in Camels, by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 2 or 3*d.*

No. 73. New Agricultural Implements for India, by G. S. HENDERSON, N.D.A., N.D.D. (Second Edition.) Price, As. 2 or 3*d.*

No. 74. Second Report on the Experiments carried out at Pusa to improve the Mulberry Silk Industry, compiled, under the direction of the Imperial Entomologist, by M. N. DE. Price, As. 4 or 5*d.*

No. 75. The Pebrine Disease of Silkworms in India, by C. M. HUTCHINSON, B.A. Price, As. 3 or 4*d.*

No. 76. Experiments with Emulsions for Protecting Camels against the Attacks of Blood-sucking Flies, by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 2 or 3*d.*

No. 77. Some Camel-feeding Experiments, by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 2 or 3*d.*

No. 78. Smuts of Jowar (*Sorghum*) in the Bombay Presidency, by G. S. KULKARNI, L.Ag. Price, As. 4 or 5*d.*

No. 79. Prussic Acid in Burma Beans, by F. J. WARTH, B.Sc., M.Sc.; and KO KO GYI. Price, As. 2 or 3*d.*

No. 80. Are Camels Susceptible to Black Quarter, Hæmorrhagic Septicæmia and Rinderpest? by H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc. Price, As. 4 or 5*d.*

No. 81. The Value of Phosphatic Manures in India and the Possibility of their Manufacture on a Larger Scale. Being evidence submitted to the Committee appointed to discuss this question (Subject IX) at the Meeting of the Board of Agriculture, Poona, 1917. Edited, with an Introduction, by W. A. DAVIS, B.Sc., A.C.G.I. Price, As. 4 or 5*d.*

No. 82. The Improvement of the Indigenous Methods of *Gur* and Sugar making in the United Provinces, by WILLIAM HULME, and R. P. SANGHI. Price, As. 8 or 9*d.*

No. 83. Progress of the Sugarcane Industry in India during the Years 1916 and 1917. Being Notes submitted to the Meeting of the Board of Agriculture in India, Poona, 1917. Edited, with an Introduction, by C. A. BARBER, C.I.E., Sc.D., F.L.S. Price, As. 5 or 6*d.*

No. 84. The Best Means of Rapidly Increasing the Outturns of Food Crops by Methods within the Power of the Agricultural Department. Being Notes submitted to the Meeting of the Board of Agriculture in India, Poona, 1917. Edited, with an Introduction, by J. MACKENNA, C.I.E., I.C.S. Price, As. 4 or 5*d.*

No. 85. Soil Drainage, by R. G. ALLAN, M.A. Price, As. 4 or 5*d.*

No. 86. A New Nematode causing Parasitic Gastritis in Calves, by A. L. SHEATHER, B.Sc., M.R.C.V.S. Price, As. 4 or 5*d.*

No. 87. A Contribution to our Knowledge of South Indian Coccidæ, by T. V. RAMAKRISHNA AYYAR, B.A., F.E.S., F.Z.S. (*In the press.*)

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA—(*Concld.*)

No. 88. Cawnpore-American Cotton: An Account of Experiments in its Improvement by Pure Lime Selection and of Field Trials, 1913–1917, by B. C. BURT, B.SC., and NIZAMUDDIN HAIDER. Price, As. 10 or 1*s.*

No. 89. Second Hundred Notes on Indian Insects. (*In the press.*)

No. 90. A Malarial Parasite in the Blood of a Buffalo, by A. L. SHEATHER, B.SC., M.R.C.V.S. (*In the press.*)

INDIGO PUBLICATIONS.

No. 1. A Study of the Indigo Soils of Bihar. The Urgent Necessity for Immediate Phosphate Manuring if Crops are to be Maintained, by W. A. DAVIS, B.SC., A.C.G.I. Price, R. 1-4 or 2*s.*

No. 2. Present Position and Future Prospects of the Natural Indigo Industry, by W. A. DAVIS, B.SC., A.C.G.I. Price, As. 10 or 1*s.*

No. 3. The Loss of Indigo caused by Bad Settling and the means of obviating this: The use of Dhak Gum—its Effect on Yield and Quality, by W. A. DAVIS, B.SC., A.C.G.I. Price, As. 4 or 5*d.*

No. 4. The Future Prospects of the Natural Indigo Industry: The Effect of Superphosphate Manuring on the Yield and Quality of the Indigo Plant, by W. A. DAVIS, B.SC., A.C.G.I. Price, As. 4 or 5*d.*

No. 5. An Improved Method of preparing Indican from Indigo-yielding Plants, by BHAILAL M. AMIN, B.A. Price, As. 2 or 3*d.*

BOOKS.

"Indian Insect Pests," by H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S. Price, R. 1-8 or 2*s.* (*Out of print.*)

"Indian Insect Life," by H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S.; and F. M. HOWLETT, B.A. 786 pp. Price, Rs. 20 or 30*s.* (*Out of print.*)

"Wheat in India," by ALBERT HOWARD, M.A., A.R.C.S., F.L.S.; and GABRIELLE L. C. HOWARD, M.A. 288 pp. Price, Rs. 5 or 7*s.* 6*d.*

"A Description of the Imperial Bacteriological Laboratory, Muktesar: Its Work and Products," by Major J. D. E. HOLMES, M.A., D.SC., M.R.C.V.S. Price, As. 8 or 9*d.*

"Agriculture in India," by JAMES MACKENNA, M.A., I.C.S. Price, As. 4 or 5*d.*

"Some Diseases of Cattle in India. A handbook for stock-owners." Price, As. 8 or 9*d.*

"The Importance of Bacterial Action in Indigo Manufacture," by C. M. HUTCHINSON, B.A. Price, As. 2 or 3*d.*

"Report of the Proceedings of the Second Entomological Meeting, held at Pusa on the 5th–12th February 1917." Price, Rs. 3.